



# AQUIFER TREATING

## And DNAPL Treatment

Client: US Air Force  
Dover AFB, Dover, Delaware  
February 1997

In August 1995, Armstrong Laboratory's Environics Directorate selected Six-Phase Heating (SPH) as part of their program to identify technologies for treating Dense Non-Aqueous Phase Liquids (DNAPL). An expert panel reviewed various technologies and SPH was identified as a promising technology deserving further evaluation.

In February 1997, a field demonstration was performed at the Dover Air Force Base, Groundwater Remediation Field Laboratory (GRFL) to determine if SPH could heat an aquifer sufficiently to remove DNAPL contaminants. Field testing was conducted in an uncontaminated aquifer using tracer compounds to mimic DNAPL.

### TECHNOLOGY

SPH is emerging as the leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants. The in situ cleanup of DNAPL remains one of the toughest challenges facing the remediation industry. Traditional remediation technologies require years of continued application to produce even marginal results at DNAPL sites.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. This increases the volatility of contaminants. Steam is generated, and acts as a carrier gas that strips out contaminants as it rises. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means, including air stripping, activated carbon, or catalytic oxidization.

### APPLICATION

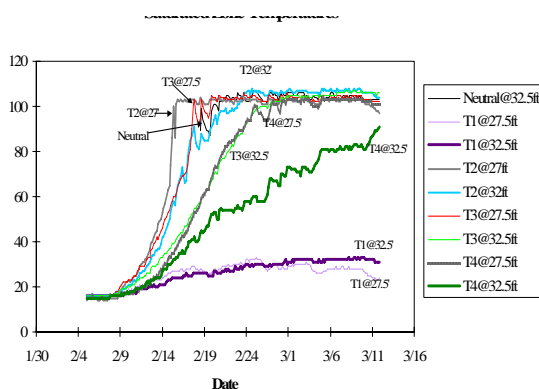
A 30-foot diameter, six-electrode heating array was installed into the upper aquifer at the GRFL site. Stratigraphy at the GRFL consists of sand, gravel, thin clay layers, and silt to a depth of 33.5-34 ft below grade (bg). A dense clay aquitard containing thin laminations of silt and fine sand is located at 34 feet bg. Groundwater was encountered at 25 ft bg. Electrodes were installed in a hexagonal pattern to a depth of 35 feet bg and were electrically conductive from 20-35 ft bg. Because a 30-ft diameter SPH array heats an area measuring roughly 42-ft in diameter, the electrodes directly heated about 800 cubic yards of subsurface. Soil and groundwater above the electrically conductive interval of the electrodes were heated by rising steam, making the total volume of subsurface treated during the demonstration equal to approximately 1,800 cubic yards.

Steam generated by SPH was collected by a Soil Vapor Extraction (SVE) system that used the electrodes and a central vent as extraction wells. Non-hazardous organic tracers were used as surrogates for DNAPL compounds commonly found at Department of Defense sites, and were injected in the center and along the edges of the heated region.

## RESULTS

Power was applied to the array beginning on February 7, 1997. Over the first 12-17 days, temperatures in the treatment volume rose to the boiling point of water. Aquifer boiling continued for another 13 days while the extracted soil vapors were sampled for the tracers. During the 30-day demonstration, 200,000 kW-hr of energy were used and 50,000 gallons of condensate were removed from the site as steam. The volume of condensate recovered roughly equaled the initial subsurface moisture present in the treatment volume.

Tracer sampling results showed some migration of tracers in the unsaturated zone but



**Saturated Zone Temperatures**

no significant migration of tracers in the groundwater. The tracer perfluoromethylcyclohexane (PMCH) was recovered fully in the extracted soil vapors, while only 35% of the tracer perfluorotrimethylcyclohexane (PTMCH) was recovered.

Sampling results also showed that tracer recovery was complete after only 21 days of heating. Energy consumption to that time was 136,000 kW-hr and condensate production was 29,000 gallons.

## CONCLUSIONS

The fate of the unrecovered PTMCH is uncertain. Its appearance in the soil vapors may have been missed during a failure of the sampling system. Moreover, soil vapor and groundwater sampling at the end of the demonstration clearly indicated that a negligible amount of PTMCH remained in the subsurface after heating.

The removal of a significant portion of the injected tracers indicates that SPH was capable of heating the aquifer to the temperatures necessary for DNAPL remediation. It also indicates that SPH has the potential to successfully treat DNAPLs in the saturated zone.

At 20% of the total demonstration budget, energy is an important part, but not a majority, of the overall costs for applying SPH. For the 30-day test, 200,000 kW-hrs of electrical energy was used. However, most of the tracers were removed during the first 21 days of heating when only 136,000 kW-hr were used. At \$0.07/kW-hr, 21 days of SPH operations required an energy expenditure of \$9,500 or approximately \$5.3/cu. yd of subsurface heated.